WHAT IS CLAIMED IS:

1. A method for shifting the bandgap energy of a quantum well layer comprising:

introducing ions into a quantum well structure at an elevated temperature and a dose of greater than $1x10^{12}$ cm^{-2}, the quantum well structure comprising:

an upper barrier layer;

a lower barrier layer; and

a quantum well layer disposed between the upper barrier layer and the lower barrier layer; and

thermally annealing the quantum well structure;

whereby quantum well interdiffusion is induced and the bandgap energy of the quantum well layer is shifted.

2. The method of claim 1, wherein the elevated temperature in the range of from about 200 °C to near the crystal damage temperature.

3. The crystal damage temperature of claim 2 is about 750°C for InP/InGaAsP materials and is about 950°C for GaAs/AlGaAs materials.

4. The method of claim 1, wherein the introducing step creates crystal site vacancies in the quantum well structure at concentration below $6x10^{19}$ cm^{-3}.

5. The method of claim 1 further comprising, during the introducing step, introducing ions into a quantum well structure that includes:

a III-V material upper barrier layer;

a III-V material lower barrier layer; and

a III-V material quantum well layer.

6. The method of claim 5 further comprising, during the introducing step, introducing ions into a quantum well structure that includes:

an InGaAsP upper barrier layer;

an InGaAsP lower barrier layer; and

an InGaAs quantum well layer.

7. The method of claim 5 further comprising, during the introducing step, introducing ions into a quantum well structure that includes:

an InGaAsP upper barrier layer;

an InGaAsP lower barrier layer; and

an InGaAsP quantum well layer.

8. The method of claim 5 further comprising, during the introducing step, introducing ions into a quantum well structure that includes:

an InP upper barrier layer;

an InP lower barrier layer; and

an InGaAsP quantum well layer.

9. The method of claim 5 further comprising, during the introducing step, introducing ions into a quantum well structure that includes:

an InP upper barrier layer;

an InP lower barrier layer; and

an InGaAs quantum well layer.

10. The method of claim 5 further comprising, during the introducing step, introducing impurity ions into a quantum well structure that comprises:

an AlGaAs upper barrier layer;

an AlGaAs lower barrier layer; and

a GaAs material quantum well layer.

11. The method of claim 5 further comprising, during the introducing step, introducing ions into a quantum well structure that includes:

an AlGaAsP upper barrier layer;

an AlGaAsP lower barrier layer; and

an AlGaAsP quantum well layer.

12. The method of claim 1 further comprising, during the introducing step, introducing a deep-level ion species.

13. The method of claim 12 further comprising, during the introducing step, introducing a deep-level ion species selected from the deep-level ion species group consisting of oxygen, gallium, fluorine, nitrogen, boron and argon.

14. The method of claim 1 further comprising, during the introducing step, introducing arsenic ions.

15. The method of claim 1 further comprising, during the introducing step, introducing xenon ions.

16. The method of claim 1 further comprising, during the introducing step, introducing phosphorus ions.

17. The method of claim 1 further comprising, during the introducing step, introducing ions into a laser waveguide quantum well structure.

18. The method of claim 1 further comprising, during the introducing step, introducing ions into a quantum well structure that further includes:

an upper cladding layer disposed above the upper barrier layer;

and introducing impurity ions into the upper cladding layer.

19. The method of claim 1 further comprising, during the introducing step, introducing ions into a quantum well structure that further includes:

an upper cladding layer disposed above the upper barrier layer; and

introducing impurity ions into the upper cladding layer such that the impurity ions are at least 0.5 micron from the upper barrier layer.

20. The method of claim 1, wherein the thermally annealing step is conducted at a temperature above 450 °C for a time period in the range of about 2 seconds to about 3 minutes.

21. The method of claim 20, wherein the thermally annealing step is conducted at a temperature above 600 °C, and

further comprising, during introducing step, introducing ions into a InP-containing quantum well structure.

22. The method of claim 21, wherein the thermally annealing step is conducted at a temperature above 700 °C, and

further comprising, during the introducing step, introducing ions into a GaAs-containing quantum well structure.

23. The method of claim 1, wherein the introducing step employs an ion implantation technique.

24. The method of claim 23, wherein the introducing step employs an implantation energy in the range of 1 eV to 3 MeV.

25. The method of claim 23, wherein the introducing step employs an implantation energy of no more than 400 KeV.

26. The method of claim 1, wherein the thermally annealing step induces a bandgap energy shift of at least 60 meV.

27. The method of claim 1 further comprising, after the introducing step and before the thermal annealing step, depositing a capping layer on the upper surface of the quantum well structure.

28. The method of claim 1 further comprising, during the introducing step, introducing ions into a quantum well structure that further includes a layer doped with a high mobility impurity, the layer doped with a high mobility impurity being back-spaced by at least 0.1 μm from at least one of the quantum well layer, the upper barrier layer and the lower barrier layer.

29. The method of claim 1, wherein the introducing step employs an implantation technique to introduce ions into a substrate that includes the quantum well structure such that the ions are located at least 0.5 microns away from the quantum well structure.

30. The method of claim 1, wherein the introducing step employs an implantation technique to introduce ions into a substrate that includes the quantum well structure such that the ions are located less than 0.5 microns away from the quantum well structure.

31. The method of claim 1, wherein the introducing step employs a focused ion beam.

32. The method of claim 1, wherein the introducing step employs a dense ion plasma.

33. A method for shifting the bandgap energy of a predetermined portion of quantum well layer comprising:

forming a patterned mask layer on a quantum well structure, the quantum well structure including:

a first barrier layer;

a second barrier layer; and

a quantum well layer disposed between the first barrier layer and the second barrier layer;

implanting ions into a predetermined portion of the quantum well structure, at a temperature in the range of from about 200 °C to about 700 °C, using the patterned mask layer as an implant mask; and

thermally annealing the quantum well structure,

whereby quantum well interdiffusion is induced and the bandgap energy of the predetermined portion of the quantum well layer is shifted.

34. The method of claim 33, wherein the forming step forms a patterned stress-inducing mask layer.

35. The method of claim 33, wherein the forming step forms an SiO_2 patterned stress-inducing mask layer.

36. The method of claim 33, wherein the forming step forms a patterned stress-inducing mask layer on a substrate that includes the quantum well structure and wherein the patterned stress-inducing mask layer is formed of a material with a thermal coefficient of expansion that is at least 10 times different than the thermal coefficient of expansion of the substrate.

37. The method of claim 36, wherein quantum well intermixing is induced with a spatial resolution of less than 3 microns.

38 ~~37~~. The method of claim 36 further comprising, during the forming step, forming a patterned mask layer that includes a plurality of patterned mask layer portions, each of the

plurality of patterned mask layer portions having a thickness that is different than the thickness of the other patterned mask layer portions, and

during the implanting step, implanting ions into predetermined portions of the quantum well structure using the patterned mask layer to control the penetration of ions into the predetermined portions of the quantum well structure.

39 ~~38~~. A method for shifting the bandgap energy of a predetermined portion of quantum well layer comprising:

forming a patterned stress-inducing mask layer on a quantum well structure;

implanting ions into a predetermined portion of the quantum well structure at an elevated temperature, using the patterned stress-inducing mask layer as an implant mask; and

thermally annealing the quantum well structure,

whereby quantum well interdiffusion is induced and the bandgap energy of the predetermined portion of the quantum well structure is shifted with a spatial resolution of less than 3 microns.

40 ~~39~~. A method for shifting the bandgap energy of a quantum well layer comprising:

introducing ions into a quantum well structure at a temperature in the range of from about 200 °C to about 700 °C, the quantum well structure including:

an upper barrier layer;

a lower barrier layer; and

a quantum well layer disposed between the upper barrier layer and the lower barrier layer; and

thermally annealing the quantum well structure,

whereby quantum well interdiffusion is induced and the bandgap energy of the quantum well layer is shifted

41 ~~40~~. The method of claim 42, wherein the introducing step employs a dose in the range of 1×10^{11} cm^{-2} to 1×10^{15} cm^{-2} and an implantation technique with an implantation energy in the range of 1 eV to 3 MeV.

42 ~~41~~. A method for shifting the bandgap energy of a quantum well layer comprising:

introducing ions into a quantum well structure at an elevated temperature;

thermally annealing the quantum well structure,

whereby quantum well interdiffusion is induced and the bandgap energy of the quantum well structure is shifted

43 ~~42~~. The method of claim 44, wherein the introducing step uses an ion implantation technique.

44 ~~43~~. A photonic device assembly comprising:

a plurality of operably coupled photonic devices monolithically integrated on a single substrate;

wherein the plurality of operably coupled photonic devices are formed using a method that includes:

forming a patterned mask layer on a quantum well structure, the quantum well structure including:

a first barrier layer;

a second barrier layer; and

a quantum well layer disposed between the first barrier layer and the second barrier layer;

implanting ions into a predetermined portion of the quantum well structure, at a an elevated temperature, using the patterned mask layer as an implant mask; and

thermally annealing the quantum well structure,

whereby quantum well interdiffusion is induced and the bandgap energy of the predetermined portion of the quantum well layer is shifted.

45 ~~44~~. The method of claim 43, wherein the elevated temperature in the range of from about 200 °C to near the crystal damage temperature.

46 ~~45~~. The crystal damage temperature of claim 43 is about 750°C for InP/InGaAsP materials and is about 950°C for GaAs/AlGaAs materials.

47 ~~46~~. The photonic device assembly of claim 43, wherein the plurality of operably coupled photonic devices includes a low-loss waveguide, a 1x2 multi-mode interference coupler, an optical amplifier, and an optical modulator.